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SYNCHRONOUS SATELLITE NAVIGATION ON LARGE REGIONS OF THE EARTH'S SURFACE AND IN NEAR EARTH SPACE

by

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ABSTRACT The article discusses radio positioning navigational systems inside and outside China as well as the general status of development and performance characteristics associated with two generations of global satellite positioning navigational systems. It introduces the U.S. domestic civilian use positioning and communications system Geosat as well as the general status and performance characteristics associated with such regional satellite navigation and communications systems as the "dual satellite high speed positioning system" proved and empirically tested by relevent Chinese departments. As far as the characterisitics of integrated GPS and regional satellite navigation systems as well as new requirements from daily increasing users are concerned, this article puts forward the "synchronous 4 satellite passive type dual frequency false random code three dimensional positioning and concise dual direction digital communications" regional positioning navigation system in order to satisfy high precision positioning associated with the large region taking China's territory as its core--for instance, positioning associated with map making, exploration, sea transport, inland water transport, as well as highway and railroad transport vehicles, dispatching, and management; tracking and positioning associated with aviation and low orbit satellites, as well as guidance; vehicle management associated with railroad hubs, harbors, air fields, as well as large and middle sized cities, along with ship anchorage positioning, navigation, and so on. In conjunction with this, it supplies such dual direction digital message activities as call forwarding, calls for help, and contact between mobile users. The system in question is compatible with the GPS and Glonass systems and can guarantee users entry into the global system as needed. At the same time, it is capable of satisfying the two types of military and civilian requirements.

KEY TERMS Synchronous satellite Positioning Guidance

GRAPHICS DISCLAIMER

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I. GENERAL DEVELOPMENT STATUS OF RADIO SURFACE POSITIONING AND NAVIGATION SYSTEMS AS WELL AS SATELLITE POSITIONING AND NAVIGATION SYSTEMS

In the activities of human existence, positioning and navigation are basic needs. In ancient times, people made use of terrain, land forms, man made navigational markers, as well as the sun, moon, and stars in order to identify direction and position. During the labors of very long periods of feudal society with low production levels, China's laboring people very early on discovered such methods and implements for navigation and positioning as the "south pointing needle" (compass), "navigating the oceans by the stars", the "hourglass", and so on, carrying out large scale oceanic navigation activities.

Modern celestial navigation and universal navigation equipment is composed of six types of instruments--astronomical clocks, star almanacs, logs, magnetic compasses, portable telescopes, and day and night automatic star light tracking devices. They are capable of "star fixing" any location on the surface of the globe. However, they are not capable of utilization in relatively highly dynamic states. This then limits utilization on aircraft and spacecraft. They are also not capable of utilization in situations associated with relatively bad surface or aerial visibility and the appearance of magnetic disturbances. Besides this, convenience, flexibility, and positioning precision associated with utilization are all relatively bad.

In the 1930's, radio positioning equipment appeared. At close, medium, and long range, it was capable of simply and conveniently completing various types of positioning and

navigational tasks associated with different precisions. Following along with the appearance of various new models of electronic components, electrical circuit technology, and large scale and very large scale integrated circuits, ground radio navigation equipment was in the midst of development in the direction of multiple functions, automatization, high reliability, and standardization. /244

Among widely used modern ground based radio navigation systems, there are Tacan, Vor/Dme, Loran C, Omega, as well as nondirectional beacons (NDB), and radio compass (ADF), etc. Air fields use instrument land systems (ILS) and microwave landing systems (MLS). These systems are mostly distributed in developed nations and regions. China's current aviation guidance means are primarily NDB and ADF. These are means which the U.S. used in the 1950's. In the U.S., ADF and NDB have already been withdrawn into an auxilliary reserve phase. From the end of this century to the beginning of the next century, the U.S. will eliminate most current ground based military radio navigation systems, replacing them with GPS space based systems.

The appearance of space based satellite radio positioning and navigation systems is the product of a combination of the production of man made satellites in this era and the requirements of military users. It was one of the first few projects satellites were applied to (communications, remote sensing, positioning and navigation). Since the implementation of the first generation satellite guidance system "Project Transit", global systems have developed two generations all together. Making use of the regional nature of synchronous orbit fixed point multiuse positioning and communications satellites to act as forms of global system supplements as well as multiuse forms of satellite application have already appeared.

Table 1 Comparative Table on the Status of Chinese and U.S. Modern Radio Navigation System Equipment (1) System Nomenclature (2) Performance Classification (3) China (4) U.S. (5) Instrument Landing System (6) Specialized Air Field Landing System (7) There Are Approximately 1500 Systems in the Whole World. The U.S. Accounts for 50%. Approximately 100 Thousand Users. Will Be Replaced by MLS. (8) Microwave Landing System (9) Specialized Air Field Landing System (10) First Test Use Reported on in a 1992 <<Xin Wen Lian Bao (Combined News Reports)>>. At the End of the 1990's, Will Be Used Experimentally on a Small Number of Typical Air Fields. (11) There Are Now 200 System Sets. Plans Are to Reach 1250 Sets at the End of This Century. Progress in Implementation Has Been Blocked. Realization May Be Delayed 3 Years. (12) Nondirectional Electric Compass (13) Close Range Direction Finding (14) There Are Not a Large Number. However, They Are an Important Means for China's Current Aerial Navigation. (15) There Are Approximately 2200 Units in the Whole World. The U.S. Possesses 1800 Units. There Are 700 Thousand Aviation and Maritime Users. There Are Ten Thousand Military Users. However, They Have Already Become an Auxilliary Means. (16) VOR/DME (17) International Standard Close Range Radio Navigation System (Direction Finding, Range Finding. Mainly Aviation.) (18) There Are Currently 1000 System Sets. There Are Approximately 200 Thousand Users. 10 Thousand Military Users. (19) TACAN (20) U.S Forces Standard Close Range Navigation System (Primaily Maritime Navigation) (21) U.S. Navy Possesses 680 Transmission Stations. 500 Ship Borne. The Rest Are Vehicle Borne. (22) LORAN C (23) Long Range Universal Navigation System (Aviation and Maritime) (24) The South China Sea Station Link Has Already Been Built. The Bohai and Yellow Sea Station Links Have Already Begun Construction. East China Sea Station Links Are Also Being Planned. In the Next Century, Will Become China's Main Means of

Medium and Longe Range Aircraft Navigation. (25) There Are Approximately 20 Station Links in the Whole World. 20 Main Stations. Over 60 Secondary Stations. The U.S. Possesses 8 Main Stations and 32 Secondary Stations. It Is Planned to Expand with Construction of 4 Units to Compensate for Coverage Gaps. (26) OMEGA (27) Super Long Range Aviation and Maritime Global Ground Based Navigation System (Long Wave Transmission) (28) Developed and Set Up by the U.S. Navy. 8 Stations Deployed Globally. They Are Located in Norway, Liberia, Hawaii, North Dakota, Reunion Island, Argentina, Japan, and Australia. /245 (29) Table 1 Continued (30) TRANSIT Satellite Navigation System (31) All Weather Global Three Dimensional Interrupted Satellite Navigation System (32) Small Number of Terminal Receivers. About to Follow System Shut Down and Stop Use. (33) Funded and Developed by the U.S. Navy. Has Had Over 40 Thousand Users. Will Be Gradually Phased Out. To Be Replaced by GPS. (34) Naviagation Satellite Global Positioning System (35) All Weather Global Three Dimensional Continuous Real Time Satellite Navigation System (36) Has Small Number of User Receivers. Will Spread in Such Areas as Chinese Civilian Uses and So On. It Only Receives Rough Capture Codes. The U.S. Opts for the Use of NA Plan. Purposely Lowers Rough Capture Code Positioning Precision and Time Precision. (37) Developed Jointly by the Three Land, Sea, and Air U.S. Military Services. Military Users Can Reach Over 20 Thousand. Among Them, U.S. Forces Users Are Over 15 Thousand. The Rest Are NATO Member States and U.S. Ally Users. There Are Over 40 Thousand Civilian Users. This Is in the Midst of Unbroken Increases.

系统名称	性能分类	中　国	美　国
仪表着陆系统 (ILS)	机场着陆专用系统		全世界约有 1500 个系统，美国占 50%，用户约 10 万个，将被 MLS 替代。
微波着陆系统 (MLS)	机场着陆专用系统	1992 年电视《新闻联播》节目中有首次试用的报道，90 年代末将在少数典型机场试用	现有 200 套系统，计划在本世纪末达到 1250 套，实施进展受阻，可能延迟 3 年实现。
无方向性电罗盘 (NDB)	近程测向	数量不多，但为我国现行航空导航主要手段。	全世界约有 2200 个，美国拥有 1800 个，空海用户 70 万，军事用户 1 万，但已成为辅助手段。
伏尔／地美依 (VOR／DME)	国际标准近程无线电导航系统(测向测距，航空为主)		现有 1000 套系统，用户 20 万左右，军事用户 1 万。
塔　康 (TACAN)	美军标准近程导航系统(航海为主)		美海军拥有 680 个发射台站，500 个舰载，其余为车载。
罗兰 C (LORAN C)	远程通用导航系统 (航空航海)	已建成南海台链，渤、黄海台链已开始建设，计划中还有华东东海台链，下个世纪将成为我国中远程飞机导航主要手段。	全世界约有 20 个台链，20 个主台，60 多个副台，美国拥有 8 个主台，32 个副台，计划扩建 4 个，弥补覆盖间隙。
奥米伽 (OMEGA)	超远程航空航海全球地基导航系统 (长波传输)		由美国海军研制建立，全球设置 8 个台站，位于挪威、利比里比、夏威夷、北达科它、留泥旺岛、阿根廷、日本和澳大利亚。

续表 1

系统名称	性能分类	中　国	美　国
子午仪卫星导航系统(TRANSIT)	全天侯全球三维断续卫星导航系统	有少量终端接收机，即将随系统的关闭而停用。	由美国海军出资研制，曾有用户 4 万多个，将逐渐淘汰，为 GPS 所替代。
导航星全球定位系统 (GPS)	全天侯全球三维连续实时卫星导航系统	有少量用户接收机，将在我国民用等方面推广，只接收粗捕获码，美国采用 NA 计划，故意降低粗捕获码定位精度和授时精度。	由美国陆海空三军共同研制，军事用户可能达 2 万多，其中美军用户 1.5 万多，其余为北约成员国和美方同盟国用户，民用 4 万多，正在不断增多。

Table 2 U.S. 1980 GPS Replacement Plan and 1988 Replacement Plan as Well as Cost Savings After Replacement (1) Replacement System (2) Year Plan (3) Year Plan Explanation (4) Possible Yearly Cost Savings (U.S. Dollars) (5) x104 (6) Air Force Cancels Aerial Use Omega in 1994.9 . Navy Still Uses. (8) Takes 1992 GPS Full On Line as Condition. Otherwise, Renegotiate. (9) Afterwards, the Military Does Not Support. (10) Fixed Stations Stop Use in 1997. Mobile Stations Still Used. (11) Still in Use in 21st Century.

替代系统	军用替代计划			可节省的年度费用成本(美元)
	1980 年计划	1988 年计划	1988 年计划说明	
Transit	1987～1992	～1992		2280 万
Omega	1987～1996	～1995	空军于 1994.9 取消空用 Ω，海军仍用	1400 万
Loran C	1987～1996	～1995	以 1992 年 GPS 全部开通为条件，否则，再鉴定	1240 万
VOR／DME	1987～1996	～1997	以后军方不再支持	460 万
Tacan	1987～1996	～1997	固定台于 1997 年停用，机动台仍用	6800 万
NDB (Ground)(UHF)	1995～1996	21 世纪仍用		340 万
ADF(LF)	1987～1996	21 世纪仍用		490 万

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Table 3 Navigation Satellite Systems and Sovereignty (1) System Class National Sovereignty (2) Global Systems (3) First Generation (4) Second Generation (5) Large Regional

Systems (6) Domestic Civilian Use Positioning and Communications System (7) U.S. (8) Former Soviet Union (9) European Space Agency (10) TRANSIT (11) Low Altitude Satellite System Composed of Such Satellites as "Cicada", "Cosmos", and "Hope" (12) Project

① 分类 系统 主权国	② 全球系统		⑤ 大区域系统
	③ 第一代	④ 第二代	
⑦ 美国	TRANSIT(子午仪)	GPS	GEOSAT(国内民用定位通信系统 ⑥
前苏联	由"蝉"、"宇宙"、"希望"等卫星组成的低高度导航星系统	Glonass	
⑨ 欧空局		Comnav 计划 ⑫	

Using GPS as the representative global positioning system, it provides high precision three dimensional positioning associated with continuous coverage on the earth's surface as well as within a near earth range of space along with all weather, day and night, continuous time coverage. This is capable of replacing various other types of navigation systems. GPS not only resolves the problems associated with the coexistence of numerous types of navigational equipment on ships and aircraft as well as uninterrupted increases in expenses. Moreover, it fundamentally changes the status of ground based navigational systems with small coverage ranges, high construction costs, numerous operating personnel, few functions, low efficiencies, and bad positioning precision.

II. DISCUSSION OF NAVIGATION SATELLITE SYSTEMS

(I) First Generation Global Systems

First generation global satellite navigation systems are represented by the U.S. "TRANSIT" system. The former Soviet Union imitated the "TRANSIT" system and made a low altitude navigation satellite system which normally had 10 satellites. This system was composed of a mutual complementation (sometimes reserve) between a "Cicada" system (Civilian system. Composed of 4 satellites. Interval between satellite orbital surfaces was 45° right ascension.) and a military navigation satellite constellation (Composed of 6 satellites. Orbital surface interval was 30° right ascension.). Most of the military navigation satellites were "Cosmos" series. 1 satellite was designated "Hope" (Nadezhda). This "Hope" satellite also belonged to the Soviet part of international search and rescue systems (Former Soviet Union designation Cospas. U.S. designation Sarsat.) It carried Cospas transmiters on it.

The orbital altitudes of the satellites of these two systems were all over 1100km. The orbits were bipolar quasi circular orbits. They transmited dual frequency Doppler signal markers. The carrier frequencies associated with time markers and ephereris data signals were extremely close. Through the autorotation of the earth, the time period in which users and satellites met each other once was 17 minutes. On average, the time period interval for meeting each other twice was 2.5 hours. Within the over ten minutes when satellites and users met each other once, each measurement iteration required 8-10 minutes. This then very, very greatly limited the number of measurement iterations, causing the system not to possess real time

characteristics and continuity.

Comparing the first generation global satellite navigation systems and ground radio global navigation systems (Omega long wave system), they had the characteristics below: /247

(1) All were capable of operating on a global scale.

(2) The "Omega" system could provide continuous time coveage. The former were only capable of providing interrupted time coverage.

(3) "TRANSIT" system positioning accuracies were approximately 100m. "Low altitude navigation satellite systems" were approximately 80-100m. The ground based "Omega" system positioning accuracy was approximately 3km.

(4) Satellite systems did not require the use of special types of sea charts. User receivers directly outputed latitude, longitude, and altitude. Use was convenient. Corrections were not needed. When the latter was used, the assistance of special types of sea charts was required.

(5) Satellite systems generally did not require the solving of multiple reflection problems in ground radio wave propogation.

(6) Satellite systems required high one time investments. However, overall performance-cost ratios were higher than for ground based systems.

(7) Satellite counter destruction characteristics were strong. The ground measurement and control stations were set up within the nation having sovereignty, and turbulent influences from international agencies could not easily affect them.

First generation global positioning satellite systems also had clear inadequacies:

(1) Satellite and user encounter time periods were short. Time period intervals were long.

(2) Within the 17 minutes of each encouter, the time period lengths associated with 1 data measurement iteration reached 8-10 minutes.

(3) They were not capable of supplying real time measurements. They were not suited for utiliztion by such highly dynamic users as aircraft.

(4) Positioning accuracies supplied by systems were approximately 100m. They were not capable of supplying user requirements associated with demands for higher precisions.

(5) As far as polar orbit orbital drift is concerned, it created an enlargement at one end of the interval between a certain two orbital surfaces and a nearing at one end. This caused the longest time period intervals to reach 8 hours or more. At the present time, the users of these two systems (the "TRANSIT" and the "low altitude navigational satellite" systems) have basically replaced them with the two GPS and Glonass systems. Supplementing launches of replacement satellites are no longer done. Following along with the conclusion of space satellite lives, the systems will automatically terminate.

(II) Second Generation Global Positioning Systems

The GPS project began to be carried out in 1978. Since

1978, 11 experimental satellites and 16 operational satellites have be launched one after the other. At the present time, the entire configuration has already reached 24 orbiting satellites in all. In Februray 1982, the former Soviet Union submited a written request to the international electronics federation, making a formal declaration of their "global navigation satellite system" (Glonass). In October of the same year, the first group of 3 satellites was launched. There are presently 27 satellites in orbit.

As far as the satellite lay out and orbital parameters of GPS and Glonass in space are concerned, option is made, in the areas of dual frequency false random code range finding systems and radio frequencies, for the use of frequencies which are extremely close. In the realm of satellite positioning navigation, the former Soviet Union again opted for the use of imitative methods to match the U.S.

Since 1989, in the area of the development of future satellite based radio navigation systems, the U.S. and the former Soviet Union have adopted cooperative attitudes, concluding a pact for the combined development and utilization of GPS/Glonass.

On the basis of this accord, a new system composed of all GPS/Glonass satellites is capable of increasing navigational precision and the integrity and reliability of coverage. At the present time, the Russian government still adopts a cooperative stance. If cooperation is successful, non-sovereign nation users will be able to no longer consider the problem of which system to select. It is possible to use GPS/Glonass compatible receivers. In this way, there is not only an increase in the reliability associated with utilization performance. There is also a lowering of the influencing role of changes in political relationships on rights of use. /249

Characteristics of the functions provided by GPS and Glonass are as follows:

(1) Global Surface and Near Earth Space Continuous Coverage as Well as All Weather, Day and Night, Continuous Time Coverage, Along with Almost Real Time Continuous Positioning Capabilities

The satellite altitudes of these two systems are approximately 20183km. Their covered space includes the spacial activity ranges associated with such moving bodies as vehicles, ships, aircraft, near earth orbit spacecraft, low orbit satellites, space stations, space shuttles, and so on. Within this range, satellites transmit false random range finding code signals that never return to zero. The process of giving out one iteration of three dimensional positioning data coordinates only requires from a few seconds to a maximum of 30 seconds (the time period to receive global data or 1 message form length). The quasi real time continuous positioning performance and high precision three dimensional positioning performance make continuous positioning of the highly dynamic moving objects discussed above capable of realization. Due to low satellite orbits (11km) and small coverage spaces, first generation global navigation systems such as "TRANSIT", and so on, were only capable of providing interrupted positioning opportunities. The length of time periods for each iteration of three dimensional coordinate data measurements reached 8-10 minutes. Positioning precision was 100m. These drawbacks made them have no way to be used with highly dynamic users. There was also no way for them to open up other new realms of application, such as, mapping, exploration, earthquake and fire monitoring, measurements of continental plate drift, and so on.

(2) Providing Three Dimensional Speed Data and Time Functions (Precisions Better Than 1 Microsecond - 0.11 Second)

Table 4 Comparative Table of the Main Parameters Associated with the Two U.S. and Russian Satellite Navigation Systems (1) Item Nomenclature (2) Circular Orbit (3) And (4) Or (5) When Code... (6) Transmission Codes of the Various Satellites Are All Different with Regard to L1 and L2 (7) Uses the Same Frequencies (8) Spacial Position (9) Latitude and Longitude Directions (10) Geocentric Direction (11) Measurement Speed (12) Set Time (13) Code I Orbital Components 1. Orbit Shape Angle of Inclination 2. Number of Orbital Surfaces Orbital Surface Interval 3. Satellite Phase Arrangement Within the Same Orbital Surface 4. Major Semiaxis 5. Number of Satellites Associated with the Same Spacial Position Within Orbital Surfaces 6. Cycle (Hours) 7. Amount of Drift Each Day (Minutes) 8. Synchronous Cycle (Rings) II Signal Structure 1. Spectrum Expansion Signal Code 2. Frequency Band Range 3. Modulation Mode 4. Band Width 5. Code Speed 6. Transmission Frequency 7. Channel Number III Navigation Precision (Design Values)

表 4 美俄两卫星导航系统主要参数对照

(1) 项目名称	GLONASS	GPS
I 轨道部分		
1. 轨形、倾角	(2) 圆轨～65°	(2) 圆轨 63°～65°
2. 轨面数量	3	3
轨面间距	120°	120°
3. 同一轨道面内卫星布设相位	(3) 30°和 45°	60°
4. 长半轴(km)	25510	26500
5. 轨道面内同一空间位置的卫星数	(4) 2 个或 3 个	1 个
6. 周期(小时)	11.5～12	12
7. 每天漂移量(分)	−4.67	−4.06
8. 同步周期(圈)	17	16

Ⅱ 信号结构		
1. 扩谱信号码	P和C/A	P和C/A
2. 频带范围(MHz)	$L_1=1597\sim1617$	$L_1=1565.2\sim1585.7$
	$L_2=1240\sim1260$	$L_2=1217.4\sim1237.8$
3. 调制方式	BPSK	UQPSK
4. 带宽(MHz)	$B_1=5.11$ $B_2=0.511$	$B_1=10.23$ $B_2=1.023$
5. 码速率(Mb/s)	P码时，5.11 C/A码时，0.511	P码时，10.23 C/A码时，1.023
6.发射频率(MHz)	各卫星发射频率对 L_1 和 L_2 均不同： $L_1=\frac{9}{7}L_2$	用同一频率
7. 通道数	24	18
Ⅲ 导航精度(设计值)	空位： 经纬方向 100m 地心方向 150m 测速 15cm/s 定时 1μs	空位： 25～50m 测速 20cm/s 定时 100ns (C/A码)

(3) Possessing Counter Jamming Capabilities and Secure Capabilties

As far as opting for the use of false random code range finding systems is concerned, when range finding signals are submerged in strong noise signals, they pick out the range finding signals with the help of very strong autocorrelation characteristics. They are also capable of opting for the use of secured coding technology, causing transmited information to be secure. In conjunction with this, they limit other nation subscriber utilization of range finding code and ephemeris data. For instance, the U.S. carries out secured handling with regard to GPS P code signals, making P code signals change into

transmission following Y code. User receivers without Y code decoder chips have no way to make use of P code.

(4) Passive Type Positioning and Navigation with Strong Concealment Characteristics as Well as Unlimited Numbers of Users

Unidirectional global continuous electric wave passive type positioning navigation makes user receivers capable of positioning without transmiting signals. In this way, user locations will not be revealed because of transmited electric waves. This has important significance for military movements. The number of users is unlimited in the same way that there is no limit when one speaks in terms of users of a broadcasting station.

(5) One Type of Universal Navigation System

Aircraft and ships making use of the receivers of the systems in question are capable of eliminating types of ground navigation equipment (short, medium, and long range navigation positioning equipment as well as direction finding equipment). Any user only needs to be equiped with 1 GPS receiver and will then be capable of adapting to voyages of short range all the way up to global courses.

(6) Strong Counter Warfare and Counter Destruction Characteristics

(7) Ground Measurement and Control Sections Associated with Global Systems Are All Capable of Installation Within the Territory of the Sovereign Nation

There are some systems (for example, LORAN-C, Omega, and fixed point synchronous satellite systems around the world) which require the setting up of stations outside the country. These are easily influenced by turbulence associated with the power of

international political agencies, causing system utilization to be interupted or partially interupted.

As far as global systems which are controled by the military departments of a small number of great powers are concerned, although they have broad realms of application and users all over the world, the majority of nations possessing user receivers, however, are only capable of making use of C/A code (rough capture code) positioning. C/A code positioning precisions are lower than P code by an order of magnitude. Since 1992, GPS--because of the U.S. making use of NA technology (electronic deception technology)--opts for the use of such means as added random trembling signal jamming, lowering star clock frequency stability, the intentional enlargement of errors in navigational ephemeris data inputed into satellites by up link data input stations, and so on, to make C/A code positioning precision drop.

Due to NA technology, there are also influences on P code precision. Seen in terms of situations which have already occured, NA techniques are not employed constantly either, but are carried out intermitantly. Precision code (P code) makes use of modulated transmission after the recomposing of classified code, making user receivers which do not possess K-Y-K decoder chips have no way to make use of P code. As a result, with the lifeblood of utilizing the GPS global system controled in the hands of the military department of the system's sovereign nation, it puts very great limits on China'a utilizing foreign global systems.

(III) COMNAV Systems

The European Space Agency's COMNAV system is also a type of global navigation and positioning system. The MBB/ERNO company

carried out in depth research on the concept of the COMNAV system. In the 1980's, it put forward an implementation plan for the future space part of the system in question. The COMNAV system space section can be composed of 6 stationary orbit communications satellites and 12 elliptical orbit satellites with high angles of inclination and large eccentricities. The latter constitute LOOPUS, that is, nonstationary satellites permanently taking up a group of geostationary loops in synchronous orbit. All 18 satellites--besides the main useful load (communications)--all carry useful navigation load. This type of COMNAV system is the responsibility of and managed by the international agency INMARSAT. The 12 elliptical orbit satellites in it are also capable of forming a new INMARSAT-III system (INMARSAT). This type of form, which strips off national sovereignty and transfers it over to the management of an international agency, makes other national users have a sense of safety and reliability.

The special characteristic of LOOPUS orbital placement is: each individual LOOPUS system is composed of 3 satellites in 3 high eccentricity orbits. The main orbital parameters are: an apogee altitude that is 39117km, a perogee altitude that is 1238km, an angle of inclination that is 63.4°, and a cycle of 12 hours. The location of the apogee point is maintained strictly on the north part of the orbital plane. The arc distance between the 3 orbital planes is 120°. The orbital characteristics discussed above, in addition to the autorotation movements of the earth, make the movement loops of 3 satellites on the celestial sphere form two equidistant track loops of points under satellites, which are consistent with each other. Due to the tracks of points under satellites being able to repeat every day, as a result, it makes satellite movement loops possess a property of maintaining positions invariable relative to the earth. It is possible to prove that there is always one satellite going through along the periphery of the track of points under satellites. At this time, the satellite in question is capable

of being used in communications and navigation activities.

Previously, it has already been brought up that COMNAV systems operating at full function--besides 6 stationary satellites--will contain 4 LOOPUS, that is, 12 large elliptical orbit satellites as well as the 8 equidistant loops of points under satellites which are formed by them. Among these, 4 loops are located in the northern hemisphere. The other 4 are located in the southern hemisphere. It is possible to achieve global coverage including the north and south poles, thereby guaranteeing that users in any region at any moment will all be able to obtain continuity of navigation and communications activities. Another clear advantage of COMNAV systems is that they are capable of gradual deployment. For instance, only setting up one small system composed of LOOPUS (the loop location is west longitude 10°) and 2 stationary satellites equiped with navigation useful loads, it is not only possible to carry out empirical verification experiments on COMNAV system concepts and characteristics, it is also possible, first of all, to put on line European region navigation and communication activities. On this foundation, gradual increases in the numbers of satellites in orbit and expansion of activity coverage ranges realize full function global coverage operational COMNAV systems.

There are 2 basic characteristics of COMNAV systems:

1. Useful navigation loads riding on commercial communications satellites make the two types of communications and navigation satellites combine into one. In this way, it is possible to very, very greatly reduce costs and serve dual communication and navigation uses.

2. The latitudes of the European region are on the high side. In order to satisfy a continuous coverage capability for regions above 75° north and south latitude (including the north

and south pole regions), satellites are deployed in large elliptical orbits. Satellites in single stationary orbits are not capable of effectively seeing the regions of the globe above and below 75° north and south latitude. At least 4 satellites are required and only then is it possible to satisfy the requirement for users in any region to use COMNAV systems at any instant. As a result, realizing COMNAV systems must have high eccentricity large ellipitical orbit satellites coordinated with each other. /251

(IV) Geostar--U.S. Civilian Detection, Ranging, and Communication System

The functions of satellite radio positioning activities (RDSS) include navigational positioning and the carrying out of communications associated with moving bodies as well as border regions. The RDSS characteristic which is most important is the possession of a capability to carry out navigation and communications at the same time. In actual applications, this point is very necessary. The U.S. Geostar civilian detection and ranging communication satellite system is then a type of RDSS system. It is also capable of expanding to become a global system. The U.S. Geostar Company which set up this system in 1983 carried out system plan design and development.

Information supplied by the Geostar system is three dimensional latitude, longitude, altitude location information. Use is made of central ground station location data which has already been measured many times and stored in complicated computers, and it is possible to calculate average speeds. It is not capable of providing communications services between radio navigation and signal transceivers. User signal transceivers are able to be installed on aircraft and vehicles moving on the ground, or installed at fixed points, or be in portable form. Portable form transceivers are equiped with digital key boards

and liquid crystal displays. Man portable type signal trasceiver positioning precision is 4.5m. Positioning precisions of airborne and vehicle borne equipment is 1m. Under the worst conditions, it is 7m. Basic measures guaranteeing this type of precision are to place at intervals of every 200-300km datum receiver stations in a network at locations which are already precisely known. In this way, opting for the use of differential processing, it is possible to eliminate ionospheric delay and atmospheric delays. Through informational data on precise positions provided by central stations, transmissions are made to users through satellite relays. The space component of the Geostar system is, at the present time, only composed of 3 fixed point satellites located at 70°, 100°, and 130°. These are, in respective order, 1#, 2#, and 3# satellites. Besides these, there is also 1 satellite to act as an orbiting spare.

The surface part of the Geostar system is composed of a central station and fixed datum stations distributed in a grid. The central station is composed of parabolic antennas to receive data from the 3 satellites, tracking and command equipment, as well as complicated computers. Their role is to send query signals to users through satellite relays, to receive answer signals as well as concise digital signals sent by users through satellite relays, and to gather various types of datum station calibration data associated with user vicinities through ground links. The role of fixed ground datum stations is to make use of difference methods to calibrate positioning precisions in the vicinities of users.

User signal transceiver and satellite up and down link signal frequencies are:

Up link 1610-1626.5MHz   Down link 2483.5-2500MHz

Central station and satellite up and down link signal

frequencies are:

Up link (only refers to 2# satellite at 100° longitude)

6525-6541.5MHz

Down link 5117-5183MHz

1. Geostar Satellite Operating Processes

The ground central station takes transmited query signals at 6533.2MHz frequency modulated at speeds of 100 iterations per second and sends them in narrow beams to 2# satellite. Through 2# satellite, wide beams of left hand circular polarized waves with a center frequency of 2491.75MHz are transmited to ground coverage area users. User signal transceivers are generally set in the receive mode. Only when it is necessary to position or communicate are transmission channels then opened up. After transmission channels are opened, answer signals are transmited set off by the query signals received. If the time of transmission of the central ground station query signal is to, the answer signal times of the certain users receiving are t1, t2, and t3 (going through the 3 satellite relays). The respective distances from the central station to the 3 satellites are R1, R2, and R3. The pseudo ranges of users to the 3 satellites are, respectively, $\rho 1$, $\rho 2$, and $\rho 3$. Then,

1

$$\rho_1 = C/2(t_1 - t_0) - R_1$$
$$\rho_2 = C/2(t_2 - t_0) - R_2$$
$$\rho_3 = C/2(t_3 - t_0) - R_3$$

$\rho 1$, $\rho 2$, and $\rho 3$ go through datum station difference processing to eliminate atmospheric signal propogation errors as well as other errors and, after that, the true distances of users from the 3 satellites are obtained. Substituting into coordinate equations, it is possible to arrive at the three dimensional user position coordinate latitude, longitude, and altitude. /252

Due to the fact that replies to query signals are one part of large amounts of required user signal transceiver positioning, the sequence in which the reply signals they send go through satellite relays and are transmited to the ground central control station is confused. However, in the 3 reply signals associated with each individual user (changed into 3 after going through 3 satellite relays of different positions and courses), the user serial number identification code is fixed. It is possible for the central control station computer to use this to check the 3 reply signals associated with the same user. After going through position calculations, the result data codes are modulated onto basic band signals. Finally, they are modulated onto a 6533.2MHz radio frequency, sent to satellites, and transmited to users. Computers are also capable of taking the positioning data for the iteration in question and the stored detection and range finding data for the previous iteration and determining the average speed associated with the time period

interval between the two iterations, providing this to the user.

2. Basic Geostar Characteristics

(1) The Geostar system is a large region, fixed satellite dual positioning and communications system. The quasi global system is simply nothing more than a few of this type of regional system arranged in connection with each other ringing the equator. Each region requires independent space subsystems and surface subsystems.

(2) Geostar systems opt for the use of fixed point satellite relay reply type communications and positioning methods. Technical difficulties are all resolved at central ground stations, making satellite borne navigation systems and user signal transceivers simple and cheap. Central control stations have movement control functions and a dominant position.

It is easy for them to calculate and collect fees, and they are convenient for business management.

(3) Dual positioning and brief message communication functions satisfy user needs to make required reports of their own shifting locations during positioning or to call help or for required communications.

(4) Geostar systems are systems for civilian use. They are limited for military applications. For instance, reply type positioning and dual direction brief digital communications do not possess concealment, regional coverage does not have global strategic and tactical capabilities, central ground station counter destruction capabilities are bad, and so on.

(5) Geostar systems are designed as supplementary systems for civilian use, primarily aimed at domestic U.S. distress calls without GPS and two way mobile communications functions between users. Within its coverage region, speaking in terms of positioning and navigation, there are such global systems as GPS and so on (For example, they all opt for the use of difference techniques. GPS positioning precision is better than Geostar's.). Speaking in terms of communications, there are specialized communications satellites. There are also small, low orbit satellite "Iridium" systems supplying voice communications to individual telephone services.

(6) There are upper limits on the user capacity of Geostar systems. In signal transmission systems, option has been made for the use of such multiple address techniques as frequency division, time division, code division, space division, and so on, and users have reached several millions. Other users, who only need positioning, can opt for the use of GPS.

When carrying out brief message communications, Geostar is capable of using the small key boards and liquid crystal screens on user receivers, taking message text and keying it into the communications information section in the response signal format.

In conjunction with this, user numbers are keyed into the send message square and receive message square, and that is all.

III. CURRENT STATUS OF CHINESE SATELLITE NAVIGATION AND POSITIONING AS WELL AS "DUAL SATELLITE QUICK MEASURE"

General Status of System Demonstration (Omitted)

IV. TENTATIVE PLAN FOR SYNCHRONOUS FOUR SATELLITE POSITIONING SYSTEM (OMITED)

V. CONCLUDING REMARKS

Filling the lack of a Chinese positioning and navigation satellite system as quickly as possible can very, very greatly improve the lagging situation associated with China's ground radio navigation and positioning system. It has great significance with regard to developing the national economy of China and strengthening military power. The synchronous orbits occupied by "four satellite systems" will be the most crowded among satellite orbits from now on. China is one of the small number of nations in the world capable of the independent, autonomous launching of advanced synchronous satellites. However, the number of satellites in orbit is still relatively small. Up to the end of this century, launch missions for Chinese synchronous orbit communications satellites, weather satellites, and foreign satellites are relatively frequent--something more than 10. In the next century, if it is possible to arrange multipurpose positioning, navigation, and communications satellites, it will also be beneficial to making China occupy relatively numerous synchronous orbit positions as quickly as possible.

With regard to the introduction of "four satellite systems", this article is a conceptual framework on the foundation of an

introduction of GPS and Geostar. Full detailed and rigorous proofs as well as introductions of designs are still not capable of taking the place of this intelligence topic. As far as limited levels of information are concerned, we have only made a few crude, imperfect, and nonrigorous explanations. There are certainly a great many errors and shortcomings. We hope for criticism and correction.

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